Effects of Moisture Added at Lint Slide on Lint Quality and Bale Weight in Humid Cotton-Growing Areas

By A. C. Griffin and E. A. Harrell

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Purpose and Scope

Like many other textile fibers, cotton is hygroscopic. This natural ability to receive moisture from or release it to the atmosphere is responsible for the continual variation of moisture content as it seeks to come to equilibrium with atmospheric conditions. Moisture equilibrium of cotton lint is a real quantity, as evidenced by variations in bale weight between the time the bale is received at the storage warehouse after leaving the gin, and the time it reaches the spinning mill. The change in bale weight is a consideration in marketing and a factor in price determination, as it often makes the difference between profit and loss when the bale moves through trade channels.

In recent years some gins have added moisture to the lint at the lint slide, for one or more of several reasons. These reasons include improving the feel of the sample, affording easier and safer bale pressing, and restoring moisture lost in drying the seed cotton.

The tests of 1953–54 and 1954–55, reported in this publication, were conducted for two purposes: (1) To determine the effect on lint quality of adding moisture to cotton at the lint slide; (2) to determine the effect of lint-slide moisture addition on bale weight during storage. The results of these tests have provided considerable useful information on these subjects.

Description of 1953–54 Tests

In 1953–54, 3 series of tests were run. Each series involved 6 bales of cotton, handpicked from a single field and ginned 1 bale after the other with no changes in ginning machinery. The ginning setup comprised 2 stages of drying with 2 tower driers, a 7-cylinder cleaner, extractor-feeders, 80-saw gin stands, and lint cleaners (fig. 1).

Different moisture conditions were established for each of the six test bales in each series. This was done by controlling drying temperatures and by using spray nozzles to apply moisture to lint while it was in the lint slide after leaving the condenser (fig. 2). Except as noted,

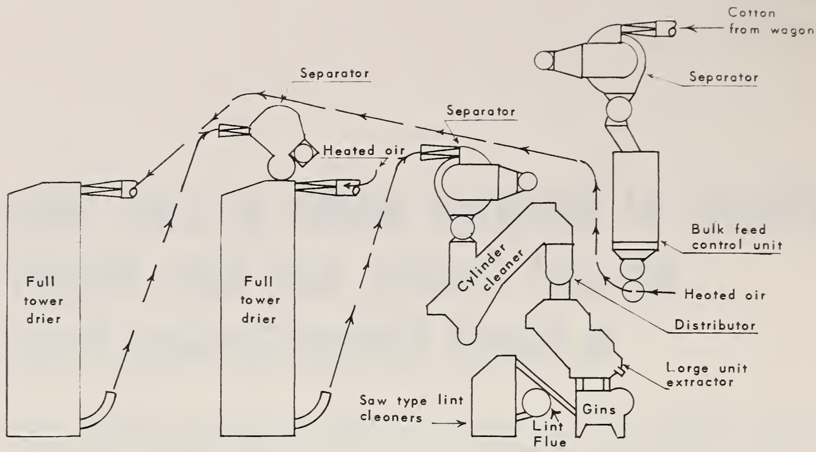

Figure 1.—Drying, cleaning, extracting, and ginning machinery used in preparing bales for storage tests of 1953–54.

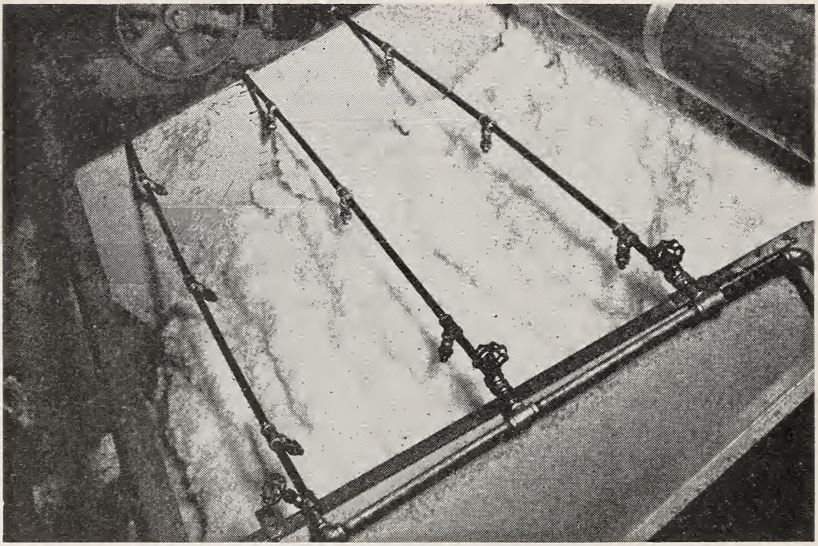

Figure 2.—Three banks of three misting nozzles used for controlled rates of moisture addition to lint in the lint slide after ginning.

the following were the test conditions for the six bales in each of the three series:

Condition

1 Drier No. 1 at ambient temperature (no drying).
Drier No. 2 at ambient temperature (no drying).
No moisture added at lint slide.

2 Drier No. 1 at 230° F.
Drier No. 2 at 180° F.
No moisture added at lint slide.

Condition

3 Drier No. 1 at 230° F.
Drier No. 2 at 180° F.
Light moisture application of tapwater at lint slide (13.6 pounds per bale).

4 Drier No. 1 at 230° F.
Drier No. 2 at 180° F.
Light moisture application at lint slide of tapwater with wetting agent (13.6 pounds per bale).

5 Drier No.1 at 230° F.
Drier No. 2 at 180° F.
Heavy moisture application of tapwater at lint slide (58.6 pounds per bale).[1]

6 Drier No. 1 at 230° F.
Drier No. 2 at 180° F.
Heavy moisture application at lint slide of tapwater with wetting agent (58.6 pounds per bale).[1]

During the ginning of the 18 test bales, samples of seed cotton and lint were taken from each bale, to provide data on foreign-matter content, moisture content, classification, fiber quality, and spinning performance.

Immediately after the bales were ginned, they were carried to the local compress warehouse, where they were weighed and subjected to customary warehouse procedures during 10 weeks (70 days) of storage, except that no samples were removed from them during the storage period nor were they again pressed. Each bale was weighed daily for 3 weeks, then 3 times a week for 4 weeks, then once a week for 3 weeks. Compress equipment was used for the weighings. This storage period ended in December, when a blowing rain wet some of the bales.

At the end of the storage period, the bales were returned to the U. S. Cotton Ginning Research Laboratory, Stoneville, Miss. There they were opened for examination, and samples were taken for comparison with the samples collected at the time of ginning. To prevent possible discrepancies occasioned by sample-testing conditions, the samples taken before storage were held until those taken after storage had been collected. Thus, both sets of samples were submitted at the same time for laboratory analysis.

Results of 1953–54 Tests

Lint Moisture Content

Test condition 1 produced lint having 5.5 percent moisture content. Drying alone (condition 2) gave lint with a moisture content of 3.9 percent. The bales which received light applications of moisture after drying had their lint moisture content raised to 5.2 percent (conditions 3 and 4). Those that received heavy moisture applications had lint moisture content of 10.5 percent (conditions 5 and 6). (Table 1.)

Of special interest is the fact that all bales entering storage with moisture content below 7 percent absorbed moisture, whereas all bales

[1] In the first series only, the rate of moisture addition to bales 5 and 6 was 82 pounds per bale. This quantity was added to simulate flooding conditions which may occur when a lint-slide moisture restoration system does not have an automatic cutoff.

TABLE 1.—*Effects of 10 weeks (70 days) of compress storage and 6 lint-moisture test conditions on fiber properties of lint cotton, packaged in standard-density bales, to which moisture was added at the lint slide during ginning (tests of 1953–54)* [1]

Property affected	Test conditions					
	No drying; no moisture restoration (condition 1)	Drying in 2 tower driers, and—				
		No moisture restoration (condition 2)	Light application at lint slide of—		Heavy application at lint slide of—	
			Moisture only (condition 3)	Moisture with wetting agent (condition 4)	Moisture only (condition 5)	Moisture with wetting agent (condition 6)
Lint moisture:						
Before storage____percent__	5. 5	3. 9	5. 2	5. 2	10. 5	10. 5
After storage_______do____	6. 2	5. 7	6. 0	6. 2	8. 1	8. 0
Lint grade:						
Before storage_____index__	103. 8	104. 5	104. 6	104. 6	104. 8	104. 6
After storage_______do____	104. 2	104. 3	104. 6	104. 2	104. 4	104. 2
Lint grade:						
Before storage designation__	SM	SM+	GM−	GM−	GM−	GM−
After storage_______do____	SM	SM+	GM−	GM−	SM+	SM
Upper half mean length:						
Before storage_____inches__	1. 04	1. 02	1. 02	1. 00	1. 01	1. 00
After storage_______do____	1. 05	1. 01	1. 03	1. 01	1. 01	1. 02
Tensile strength:						
Before storage 1,000 pounds per square inch__	79	80	79	79	78	78
After storage_______do____	81	80	81	82	83	82

[1] This table does not include data for the very heavily wet bales which received 82 pounds of moisture per bale.

entering storage with moisture content above 7 percent lost moisture (fig. 3). After 10 weeks of compress storage, there was no practical difference between comparable bales that had received tapwater alone and those that had received tapwater containing a 1-percent solution of wetting agent.

The two very heavily wet bales (82 pounds of moisture added per bale) went into storage with moisture content of 15.4 and 18.8 percent, respectively. By the end of the storage period, they had lost 10.2 and 12.4 percent (or 25 and 30 pounds) of moisture, respectively.

Fiber Length

One important fact brought out in these tests is that adding moisture to ginned lint fails to improve fiber (or staple) length over that of lint dried with no moisture added (condition 1). That shortening of

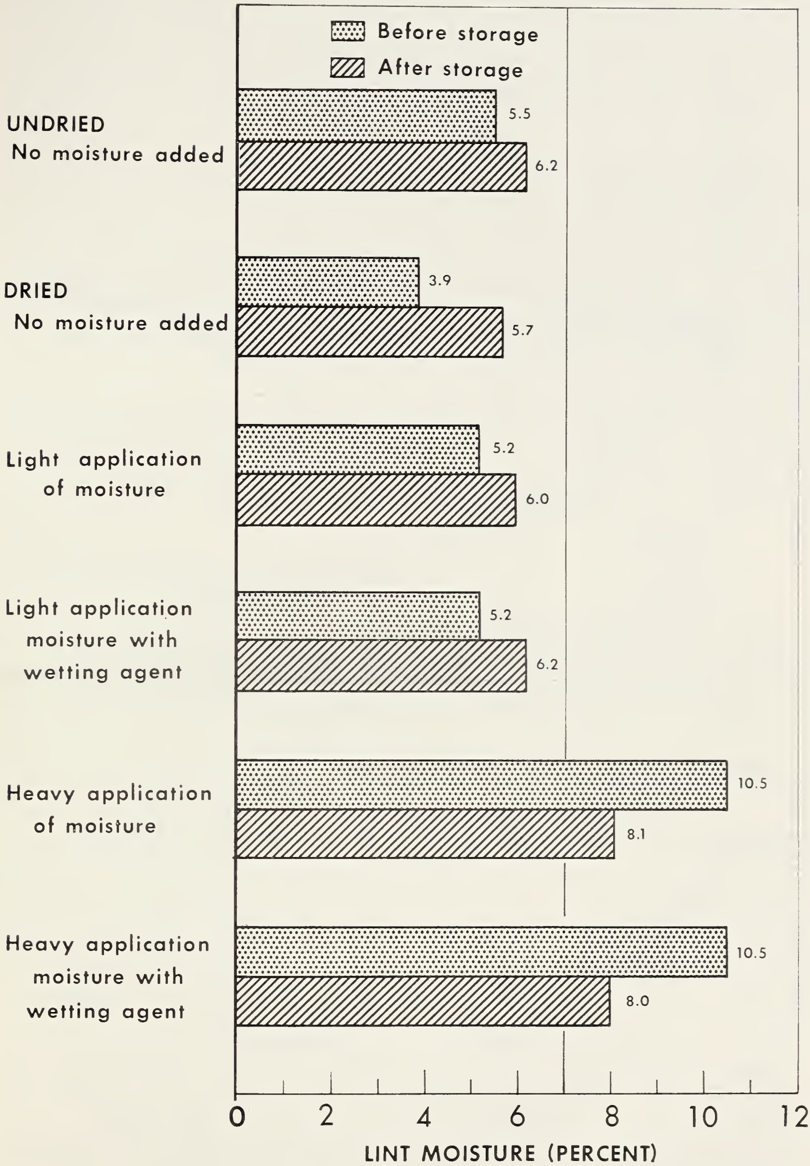

FIGURE 3.—Effects of 10 weeks (70 days) of compress storage on moisture content of bales to which moisture and wetting agent were added at the lint slide (tests of 1953–54).

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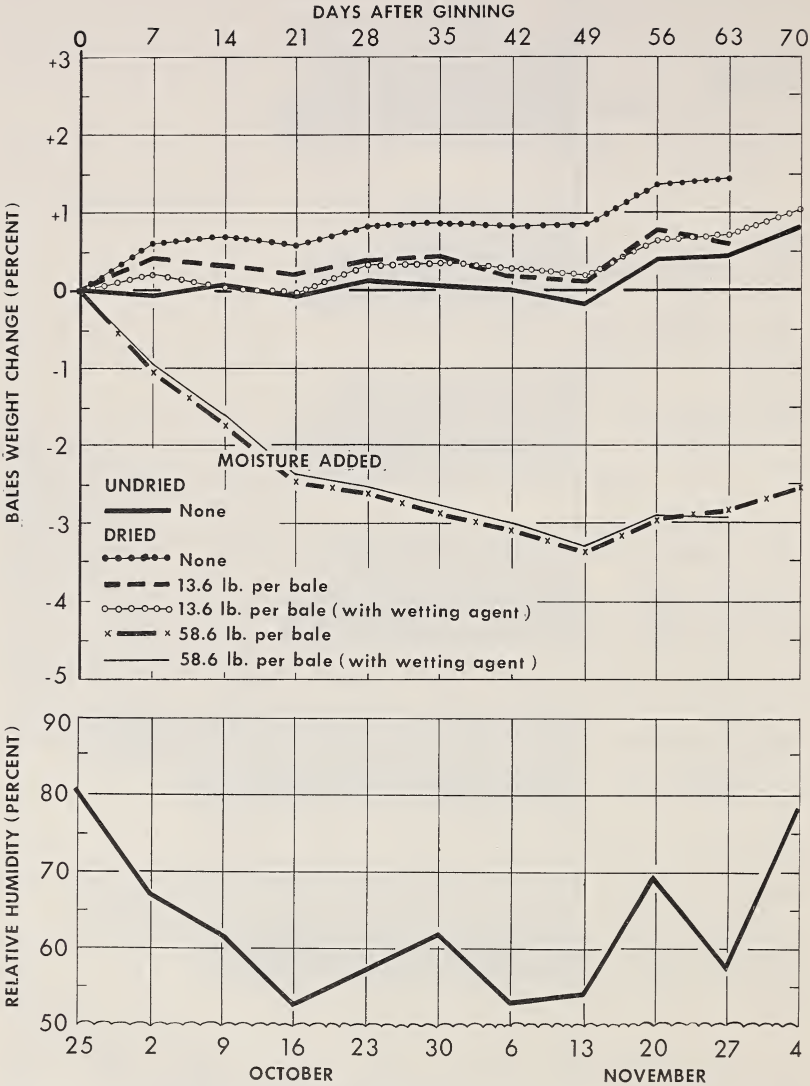

Figure 4.—Variations in ambient relative humidity and changes in weight of standard-density bales, packaged under 6 moisture conditions and stored for 10 weeks (70 days) in compress at Leland, Miss. (tests of 1953–54).

fiber may result from the drying of seed cotton is readily seen by comparing the data for conditions 1 and 2 (see table 1). This shortening, as well as failure to restore fiber length by adding moisture to ginned lint, was detected by both the commercial cotton classer and the fibrograph; and it was observed in the samples taken after 10 weeks (70 days) of storage, as well as in the samples taken before storage.

Lint Grade

Compress storage for 10 weeks (70 days) had no effect on lint classification. Some grade improvement, however, was noticeable for all bales ginned with drying as compared with those ginned without drying (condition 1). This was attributed to more efficient seed-cotton cleaning as a result of drying.

There was no apparent difference in grade between samples taken before storage and those taken after storage, when the lint moisture content was below 11 percent at the time the bales entered storage.

In storage, the two very heavily wet bales (those that received 82 pounds per bale of added moisture) behaved differently from the others. These two bales, which had 15.4 and 18.8 percent moisture, respectively, suffered mildew damage. When these bales were broken open for inspection, the mildew appeared most heavily concentrated at the ends of each bale, although this fungus damage was found throughout.

Weight Change and Rate of Change

As previously pointed out, there was a tendency for all bales in this test to move toward an equilibrium moisture content of about 7 percent (see fig. 3). Moisture was applied to the lint at the lint slide, to provide moisture conditions of both below and above 7 percent; consequently, some bales lost weight and some gained weight as a result of changes in moisture content.

Because the weight of each bale differed from that of the others, changes in weight for each bale were converted to percent of change from the weight at the beginning of the storage period.

Immediately apparent is the close similarity between the weight gain and loss curves for bales moistened with tapwater only, and for those moistened with a solution of tapwater and wetting agent. This similiarity exists for moisture conditions both above and below 7 percent (fig. 4). These data do not indicate that bales to which wetting agent was applied were more unstable or more variable in weight than were those to which tapwater only was added.

Differences in rate of weight change are seen as a function of both the ambient relative humidity and the potential for weight change possessed by the individual bale. This fact is illustrated by the behavior of bale weights during the period October 16–23, 1953; the bales that received heavy moisture application continued to lose weight, whereas the others gained weight.

Description of 1954–55 Tests

The tests of 1954–55 were similar to those of 1953–54. Six bales of cotton were used, but only one series of tests was conducted. Machine-picked cotton was used in these tests. The ginning setup, more elaborate than for the 1953–54 tests, consisted of a tower drier, a 6-cylinder

cleaner, a bur machine, a second tower drier, a 7-cylinder cleaner, extractor-feeders, 80-saw gin stands, and lint cleaners (fig. 5). The test conditions were as follows:

Condition

1 Drier No. 1 at ambient temperature (no drying).
Drier No. 2 at ambient temperature (no drying).
No moisture added at lint slide.

2 Drier No. 1 at 225° F.
Drier No. 2 at 150° F.
No moisture added at lint slide.

3 Drier No. 1 at 225° F.
Drier No. 2 at 150° F.
Light moisture application of tapwater at lint slide (8.6 pounds per bale).

4 Drier No. 1 at 225° F.
Drier No. 2 at 150° F.
Light moisture application at lint slide of tapwater with wetting agent (8.6 pounds per bale).

5 Drier No. 1 at 225° F.
Drier No. 2 at 150° F.
Heavy moisture application of tapwater at lint slide (35.7 pounds per bale).

6 Drier No. 1 at 225° F.
Drier No. 2 at 150° F.
Heavy moisture application at lint slide of tapwater with wetting agent (35.7 pounds per bale).

In these 1954–55 tests, the storage area was at the U. S. Cotton Ginning Research Laboratory, Stoneville, Miss., instead of in the local compress warehouse. A wooden platform was used to keep the bales off the concrete floor; and the weighing was done on a dial scale graduated in tenths of pounds (fig 6). Storage was from October 14, 1954, through January 13, 1955, a period of 13 weeks (91 days).

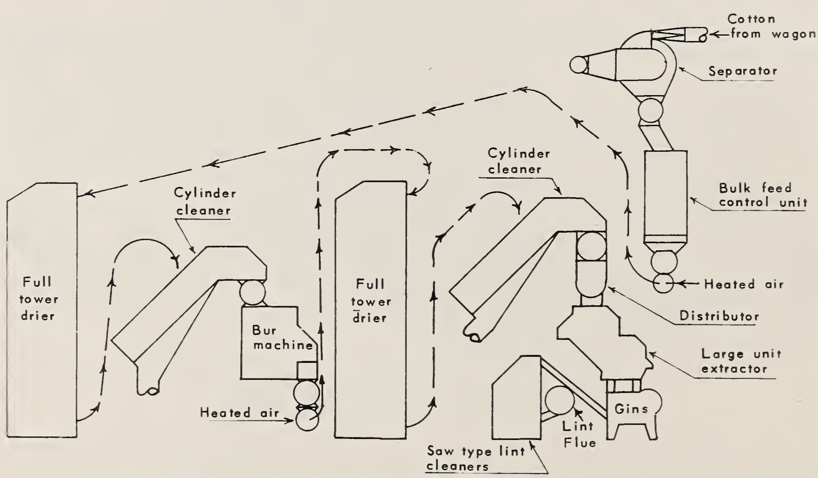

FIGURE 5.—Drying, cleaning, extracting, and ginning machinery used in preparing bales of cotton for storage tests of 1954–55.

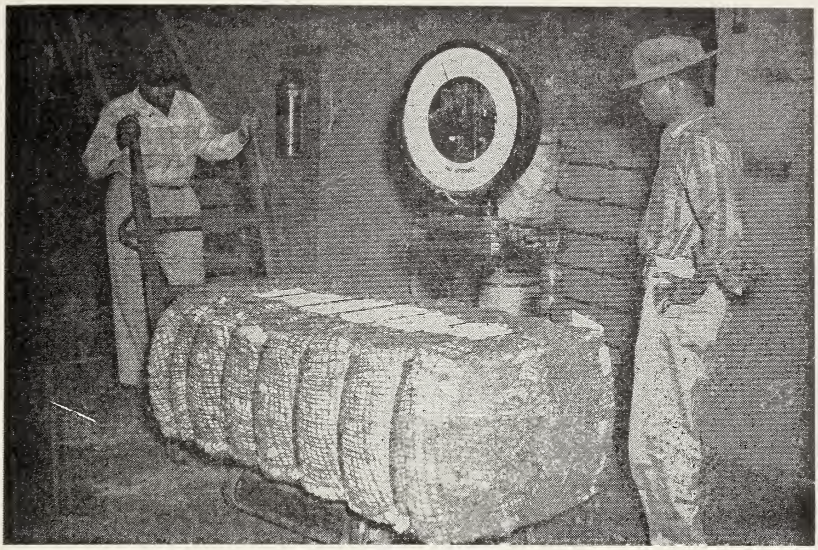

FIGURE 6.—Weighing a test bale to determine change in weight resulting from moisture absorption.

Results of 1954–55 Tests

Lint Moisture Content

The bale that was ginned with no drying and no addition of moisture (condition 1) had a lint moisture content of 8.6 percent. The other five bales were dried to 4.6 percent of moisture (table 2). The light application of moisture at the lint slide restored the moisture content to 5.0 percent, while the heavy moisture application raised the moisture content to 9.0 percent.

As in the 1953–54 tests, bales entering storage with moisture content below 7 percent absorbed moisture, while those with initial moisture content above 7 percent lost moisture (fig. 7). In other words, all bales in both tests approached 7 percent as an equilibrium. The data for figure 7 were collected at the beginning and end of the 91-day storage period and do not necessarily represent maximum or minimum values attained during that period.

The distribution of moisture within the bale at the end of the storage period is of special interest. When each bale was opened for sampling, two lint moisture samples were taken along the centerline from each of three points representing the head, center, and foot of the bale. The data show that, after 91 days, the center of the bale remained nearer its initial moisture content than did the extremities; also, that rapid bale-weight variations were caused by moisture-content changes within the outer layers of the bale (table 3). These data further indicate that these bales did not reach equilibrium within themselves, and that only by chance would they ever do so except under extended, constant ambient conditions in excess of 91 days.

TABLE 2.—*Effects of 13 weeks (91 days) of storage and 6 lint-moisture test conditions on fiber and spinning properties of lint from machine-picked cotton, to which moisture was added at the lint slide during ginning (tests of 1954–55)*[1]

Property affected	Test conditions											
	No drying; no moisture restoration (condition 1)		Drying in 2 tower driers, and—									
			No moisture restoration (condition 2)		Light application at lint slide of—				Heavy application at lint slide of—			
					Moisture only (condition 3)		Moisture with wetting agent (condition 4)		Moisture only (condition 5)		Moisture with wetting agent (condition 6)	
	Before storage	After storage	Before storage	After storage	Before storage	After storage	Before storage	After storage	Before storage	After storage	Before storage	After storage
Lint moisture......percent..	8. 6	8. 5	4. 6	6. 5	5. 0	6. 2	5. 0	6. 4	9. 0	7. 1	9. 0	8. 3
Grade..........designation..	SGO	SGO	SLM−	SLM−	LM+	LM+	LM+	LM+	LM+	LM+	LM+	LM+
Do..............index..	76	76	91	91	88	88	88	88	88	88	88	88
Staple length.......1/32 inch..	34	34	33	33	33	33	33	33	33	33	33	33
Upper half mean length inches..	1. 08	1. 08	1. 00	1. 01	1. 00	1. 00	. 98	. 99	1. 02	1. 01	. 98	1. 01
Tensile strength 1,000 pounds per square inch..	81	81	82	81	82	83	82	82	82	80	80	81
Manufacturing waste percent..	14. 53	14. 51	10. 00	10. 26	10. 49	11. 46	11. 81	11. 65	11. 18	11. 14	11. 08	10. 86
Neps number per 100 square inches of card web..	22	33	19	19	24	29	34	28	26	31	25	24
Spinning end breakage.......	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Yarn strength, 22s..pounds..	112. 6	113. 4	105. 2	104. 2	101. 6	101. 9	96. 4	96. 4	99. 3	102. 8	101. 3	103. 3
Average yarn appearance, 22s and 50s............index..	85	80	80	80	80	85	75	70	75	80	75	90

[1] Bales were pressed to standard density for storage. Ginning setup consisted of a tower drier, a 6-cylinder cleaner, a bur machine, a second tower drier, an impact cleaner, extractor-feeders, gin stands, and lint cleaners.

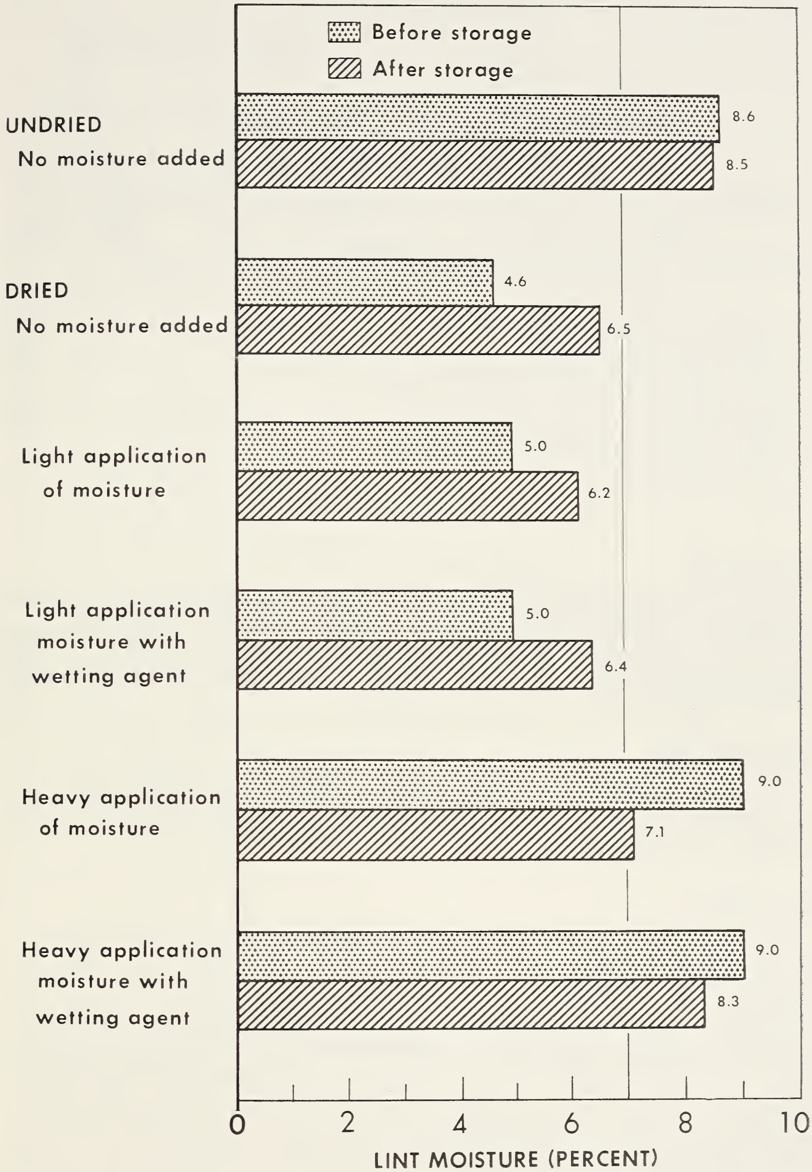

FIGURE 7.—Effects of 13 weeks (91 days) of storage on moisture content of bales of cotton to which moisture and wetting agent were added at the lint slide (tests of 1954–55).

TABLE 3.—*Distribution of moisture in standard-density bales of cotton lint after 13 weeks (91 days) of storage at Mississippi Delta ambient atmospheric conditions (tests of 1954–55)*

Test condition	Moisture content of bale				
	At time of ginning	After 91 days of storage			
		Head of bale	Center of bale	Foot of bale	Average for bale
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
1—Undried; no moisture added	8. 6	8. 4	8. 4	8. 5	8. 5
2—Dried; no moisture added	4. 6	6. 6	6. 0	6. 8	6. 5
3—Dried; light application of moisture	5. 0	6. 3	5. 9	6. 6	6. 2
4—Dried; light application of moisture with wetting agent	5. 0	5. 6	6. 3	7. 4	6. 4
5—Dried; heavy application of moisture	9. 0	6. 8	7. 1	7. 5	7. 1
6—Dried; heavy application of moisture with wetting agent	9. 0	7. 7	8. 8	8. 3	8. 3

Fiber Length

Both the fibrograph and the cotton classer detected fiber (or staple) shortening resulting from drying. Again, when no moisture was added after ginning or absorbed during the 91 days of storage, there was no increase in fiber length. This was consistent with the findings for the 1953–54 tests.

Tensile Strength

Measurements of tensile strength revealed no significant differences in strength of fiber as a result of drying, moisture restoration after ginning, or storage.

Lint Grade

In these tests, the bale dried with no addition of moisture (condition 2) was graded Strict Low Middling minus (SLM—), as compared with a grade of Strict Good Ordinary (SGO) for the undried bale (condition 1)—an improvement of one and two-thirds grades as a result of drying. Contrary to the results of the 1953 tests, the bales to which moisture was added at the lint slide were reduced one-third grade, or from SLM— to Low Middling plus (LM+). No grade changes resulting from storage were found, and no color damage from mildew or other bacterial action was observed.

Weight Change and Rate of Change

Plotting the percentage gain or loss in bale weight during storage, as a function of time influenced by ambient relative humidity, shows that the most rapid period of weight change occurred during the first week after ginning (fig. 8). Weight changes within the first

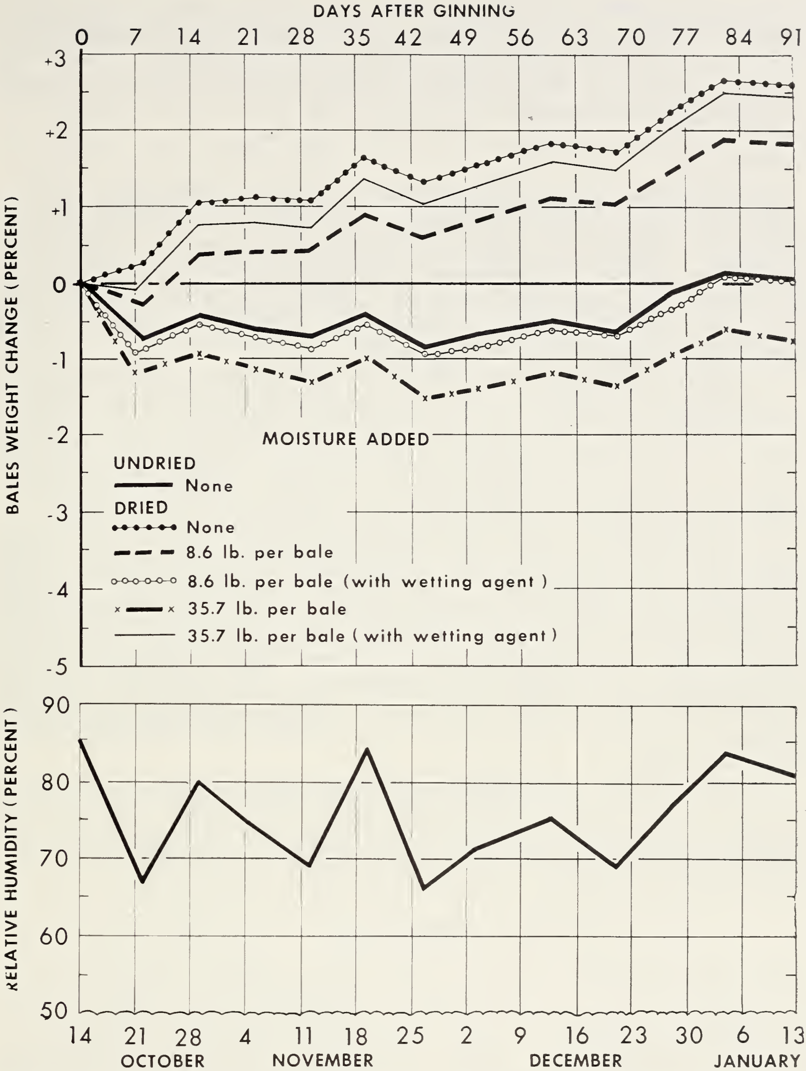

Figure 8.—Variations in ambient relative humidity and changes in weight of standard-density bales, packaged under 6 moisture conditions and stored for 13 weeks (91 days) at U. S. Cotton Ginning Research Laboratory, Stoneville, Miss. (tests of 1954–55).

month after ginning appeared to be due principally to the initial moisture content of the test bales. After 1 month, variations in bale weight closely followed average ambient relative-humidity variations, even though the overall moisture content moved toward an average equilibrium moisture content of about 7 percent.

Examination of the weight-change curves shows that the bales to which wetting-agent solution was added underwent greater weight change than did the bales to which water only was added. This was

not evident in the 1953–54 tests, but it is a logical effect inasmuch as capillary migration within baled lint is facilitated by the reduced surface tension which results from using wetting agents. These data do not indicate greater moisture retention by the bales on which wetting agent was used.

Spinning Data

The reduced manufacturing waste of the five dried bales, as compared with that of the undried bale (condition 1), was attributable to increased cleaning efficiency resulting from drying. No pattern of difference existed for variations in manufacturing waste within the five dried bales, although waste was slightly lower for the bale that was dried with no addition of moisture (condition 2) than for those that received moisture at the lint slide.

The data indicated no differences in the quantity of "ends down" (mill breaks in yarn) as a result of subjection to the six test conditions.

The number of neps in the card web was slightly lower for the dried bales. No discernible pattern of difference developed, however, and the average yarn appearance varied randomly, so that no differences could be attributed to either the test conditions or the storage.

The reductions in fiber (or staple) length, mentioned previously, were reflected in reduced yarn strength of 22s, the reduction being from about 113 pounds for the undried bale to 105 pounds or lower for the lots that were dried during ginning. These reductions in yarn strength ranged from 7 to 15 percent, with an average reduction of 10.8 percent. The important finding was that no improvement in yarn strength was attributable to addition of moisture after ginning, regardless of the quantity of moisture regained by the lint and regardless of whether it was regained at the lint slide or during the 91 days of storage.

The six test lots were all spun with the same spinning-frame adjustments, to avoid having another variable in the study. For this reason, fiber shortening occasioned by drying was ultimately reflected in reduced yarn strength at the spinning stage.

Discussion

As mentioned before, cotton lint is hygroscopic. It may therefore be expected to gain or lose moisture continually as the relative humidity about it changes. As the bale of lint increases or decreases its moisture content, its weight necessarily undergoes corresponding increases or decreases; and if the relative humidity about a bale of cotton remains constant long enough, the bale should arrive at a fixed-equilibrium moisture content and thereby attain a definite weight. Actually, however, the relative humidity may vary widely during a single day; and it may fluctuate about different levels, depending on the season of the year, the geographic location, and local weather conditions.

The rate of bale-weight change caused by adsorption and desorption of moisture is affected by several factors. Among these are bale density, ambient temperature, area of bale exposed to air, type of bale wrapping, and the differential between the actual lint moisture content of the bale and the equilibrium moisture content of the lint at existing atmospheric conditions.

It is reasonable to assume that at the time of packaging, the moisture content of lint is practically uniform in its distribution throughout the bale. Immediately after the bale is pressed, the moisture content begins to seek equilibrium with the atmospheric relative humidity. The outermost fibers are the first to be affected by the ambient relative humidity; they are also affected by the moisture content of fibers nearer the center of the bale.

Thus, it is apparent that bale-weight change resulting from processes of sorption is the effect of a combination of two moisture differentials which may function either in the same or in opposite directions.

The first of these differentials is explained as follows: When the moisture content at the surface of the bale is considered as a fixed value, it is recognized that the moisture deeper in the bale (where the moisture content may be either higher or lower than that at the surface) undergoes a capillary migration. This is the action by which moisture seeks to distribute itself more evenly within the bale.

The second moisture differential is that between the existing lint moisture content at the bale surface and the equilibrium moisture content at prevailing atmospheric conditions.

The different effects on the six test bales of the various combinations of factors from October 14 to November 12, 1954, may be observed (see fig. 8). These bales were exposed simultaneously to the same relative-humidity changes, yet the degree and rate of change among them differed, as is indicated by the slopes of the curves. Similarity in slopes of all the curves after November 12, as well as their similarity to the relative-humidity line, indicates that the moisture differential between the surface and the center of each bale was less than the difference between the surface moisture content and the equilibrium moisture content.

Summary and Conclusions

Bales of cotton lint packaged in humid cotton-growing areas (including the Mississippi Delta) at less than 7 percent moisture may normally be expected to gain weight; those packaged at more than 7 percent moisture may normally be expected to lose weight.

Whether a bale gains or loses weight depends on two factors—the actual moisture content of the bale and the equilibrium moisture content at prevailing atmospheric conditions.

Because atmospheric conditions are never constant, the weight of a bale of lint can never be constant, for lint is inherently hygroscopic.

In some areas it is common practice for ginners to replace at the lint slide some of the moisture removed during ginning. There are several reasons for this which include improving the feel of the sample, affording easier and safer bale pressing, and minimizing bale-weight changes by restoring moisture to extra dry ginned cotton.

The tests reported in this publication indicated no quality improvement in cotton to which moisture was added at the lint slide, when compared with cotton similarly dried and ginned but with no moisture added at the lint slide.

Of the 24 bales involved in these tests, no damage could be attributed to addition of moisture at the lint slide, except for the two bales packaged at 15 percent or more moisture (see p. 7). This statement does not imply that no damage will occur when the moisture content

is below 15 percent; it only means that no damage was apparent in bales having a moisture content of 9.0 percent or less.

Rapid changes in bale weight, resulting from changes in moisture content, involve primarily the outermost cotton in the bale. Considerable time is necessary for the center of a bale of lint to change its moisture content by even 1 percent.

These tests revealed no differences in lint quality or spinning properties of the bales for which a wetting agent was used as the test variable. There was some evidence, however, to indicate that such bales may change their weight faster because of processes of sorption than bales to which no wetting agent is applied.

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